Discovery of Ultra-Fast Outflows (UFOs) in Radio-Loud AGN

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Thank you to:

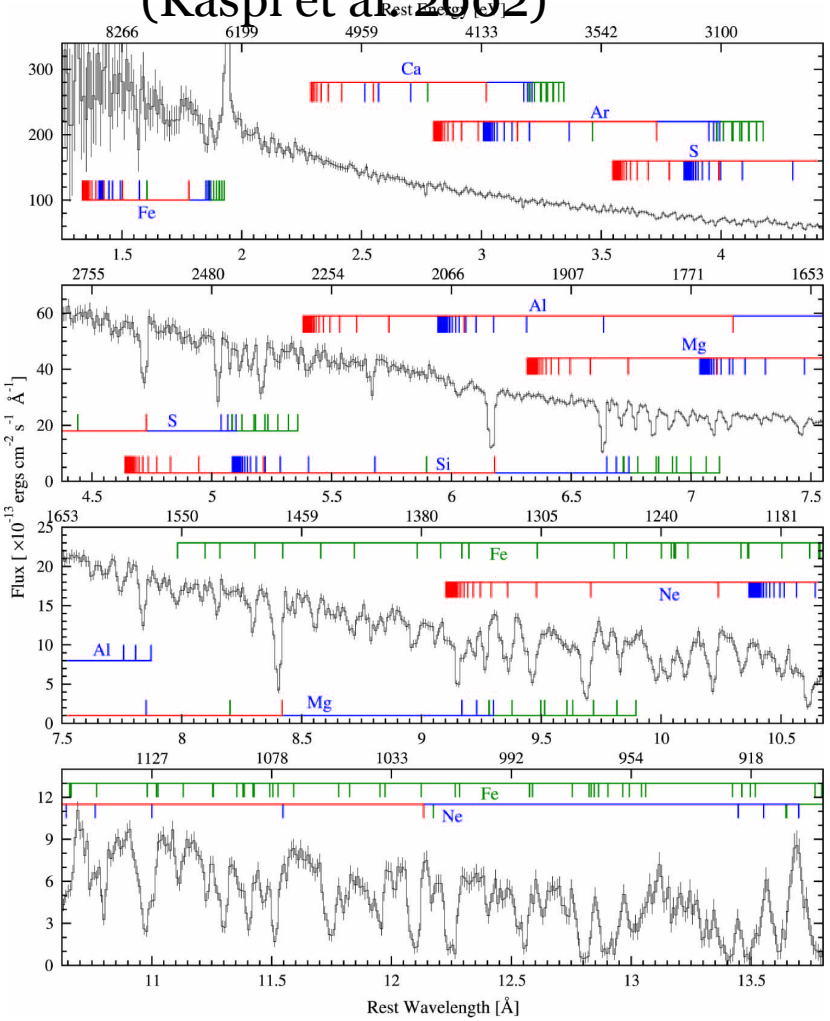
- Francesco Tombesi
- James Reeves, Valentina Braito, Lucia Ballo, Max Cappi

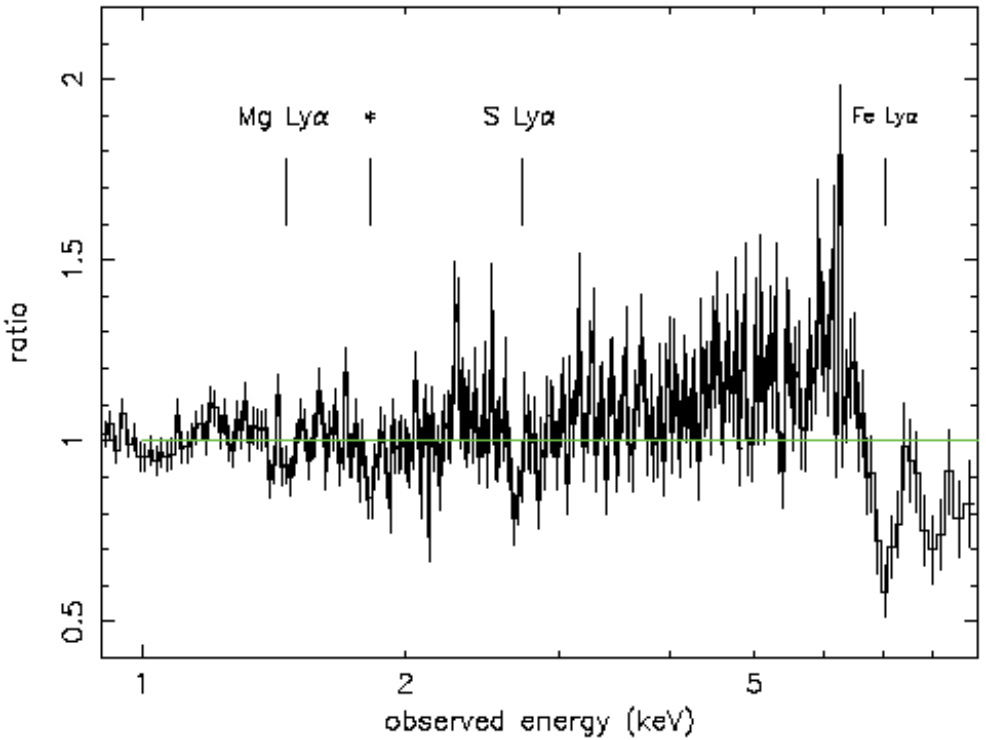
- Group Publications:

Tombesi et al. 2010, ApJ, subm
Reeves et al. 2010 ApJ, subm
RMS et al. 2009 ApJ, 700, 1473
Reeves et al. 2009 ApJ, 702, L87

Ionized gas in radio-quiet AGN

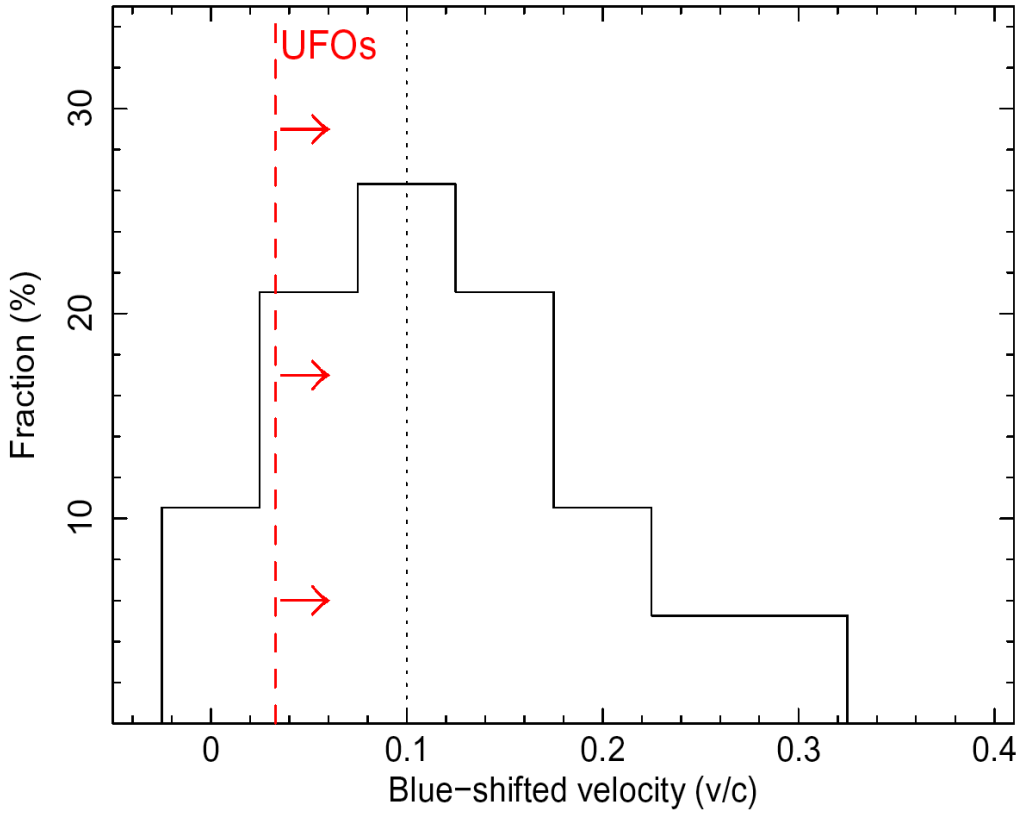
Warm gas in NGC3783
(Kaspi et al. 2002)





Ultra-Fast Outflow (UFO) in PG1211+143 (Pounds et al. 2003; Pounds & Page 2006)

UFOs common in radio-quiet AGN



Tombesi et al 2010, A&A, subm:

XMM Survey of z<0.1 Seyfert galaxies (44 sources, 104 spectra)

Around the BH in radio-loud AGN

- Until recently, little or no evidence for ionized diffuse gas on sub-pc scales
- Are the central engines of RL AGN “empty”?
- Powerful radio jet sweeping away material
- Jet only mediator of energy with large-scale environment

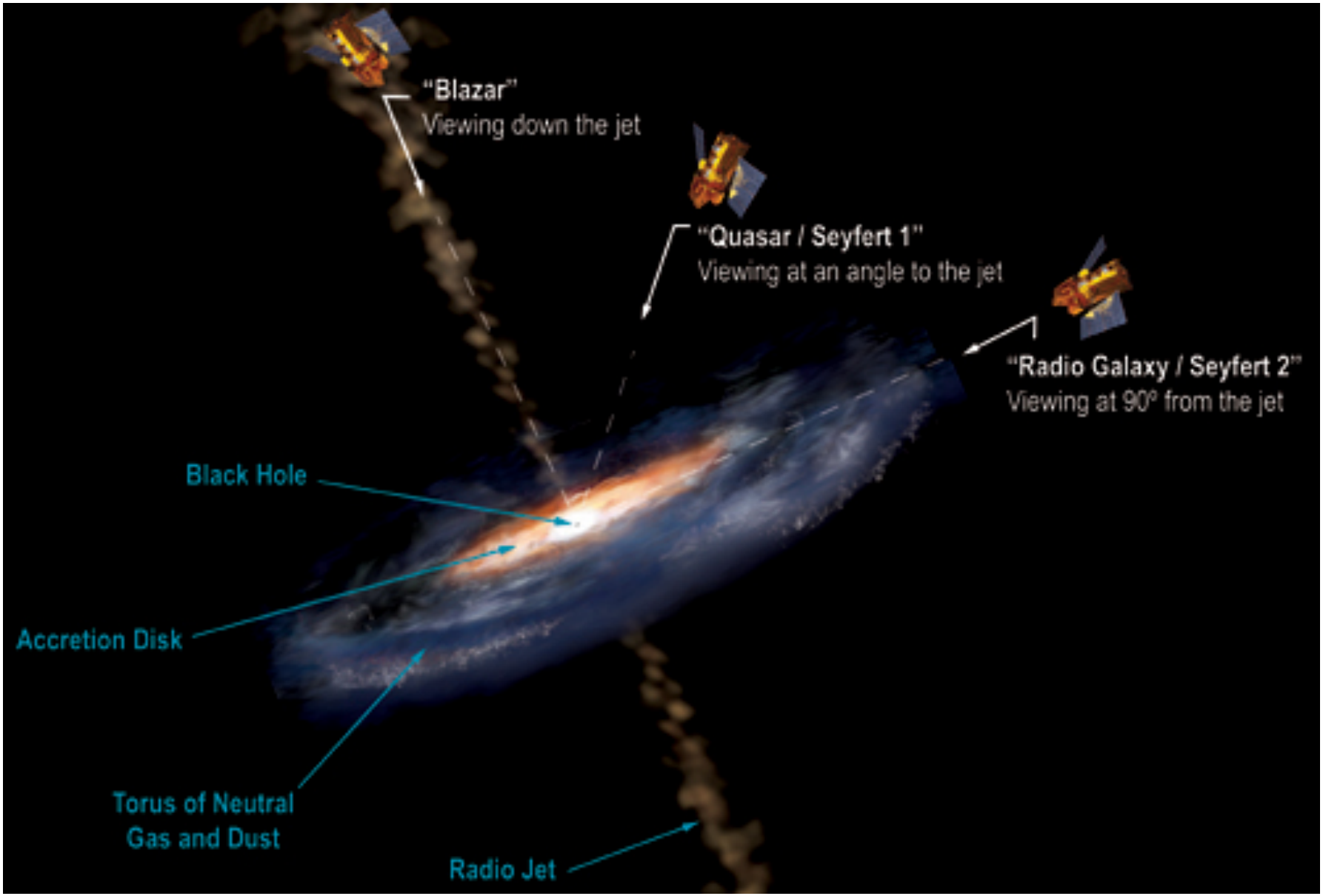
  → “**radio mode**” feedback

Tales of change

Deep Chandra & XMM gratings:

- First detection of warm absorber on kpc-scales in 3C382 (Reeves et al. 2009; Torresi et al. 2010)
- Evidence for emitter & absorber in 3C445 on sub-pc scales (Reeves et al. 2010)

Broad-Line Radio Galaxies



Suzaku observes BLRGs

Our Program: BLRGs at z<0.1

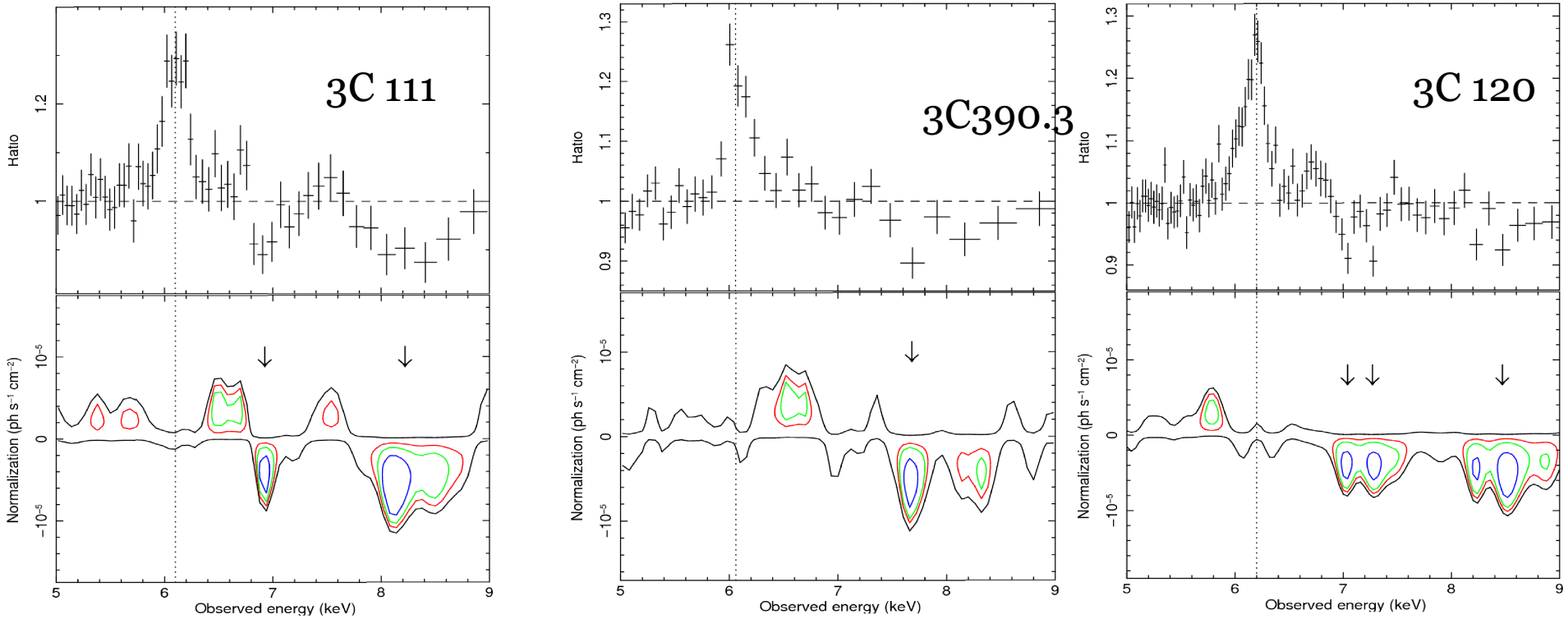
- 3C 390.3: 100 ks
- 3C 382: 100 ks
- 3C 445: 120 ks
- 3C 111: 100 ks

+ BAT spectrum from 9 months survey (Tueller et al. 2008)

In GTO Program:

- 3C 120: 160 ks (Kataoka et al. 2007)

Absorption features in 7-10 keV



Uniform spectral analysis:

- Reduction and analysis of all XIS-FI spectra in the 4-10keV
- Baseline model: absorbed power-law + Gaussian Fe K emission lines
- Absorption lines search with energy-intensity contour plots
- Detection probability from extensive Monte Carlo simulations

Source	ID	E (keV)	σ (eV)	EW (eV)	$\Delta\chi^2/\Delta\nu$	F-test	MC
3C 111	Lyα	$7.26(6.92)^{+0.03}_{-0.03}$	10^a	-31 ± 15	13/2	99.9%	99%
	Lyβ-Lyγ-Lyδ	$8.69(8.29)^{+0.13}_{-0.08}$	390^{+270}_{-70}	-154 ± 80	40/3	$\geq$99.9%	$\geq$99.9%
3C 390.3	Lyα	$8.11(7.68)^{+0.04}_{-0.04}$	10^a	-32 ± 16	14.6/2	99.9%	99.5%
3C 120a	...	$\equiv 7.25^a$	10^a	$> -29^b$	...	...	...
	...	$\equiv 7.54^a$	10^a	$> -32^b$	...	...	...
	...	$\equiv 8.76^a$	500^a	$> -160^b$	...	...	...
3C 120b	Kα	$7.25(7.02)^{+0.03}_{-0.03}$	10^a	-10 ± 5	9.4/2	99%	91%
	Lyα	$7.54(7.30)^{+0.04}_{-0.04}$	10^a	-12 ± 6	10/2	99.3%	92%
	Kβ-Lyβ	$8.76(8.48)^{+0.12}_{-0.12}$	360^{+160}_{-120}	-50 ± 13	18/3	99.9%	99.8%
3C 382	...	$\equiv 8^a$	10^a	$> -20^b$	...	...	...
3C 445	...	$\equiv 8^a$	10^a	$> -45b$	...	...	...

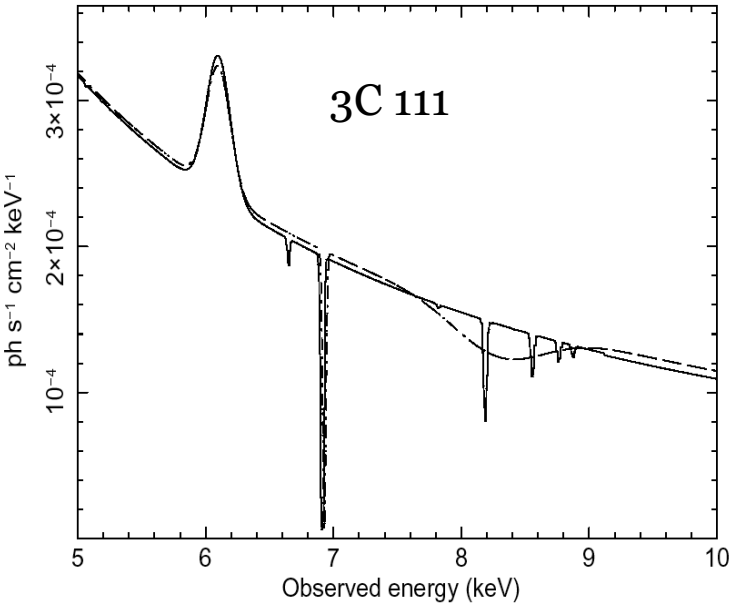
(a) Parameter held fix during the fit.
(b) Equivalent width lower limit at the 90% level.

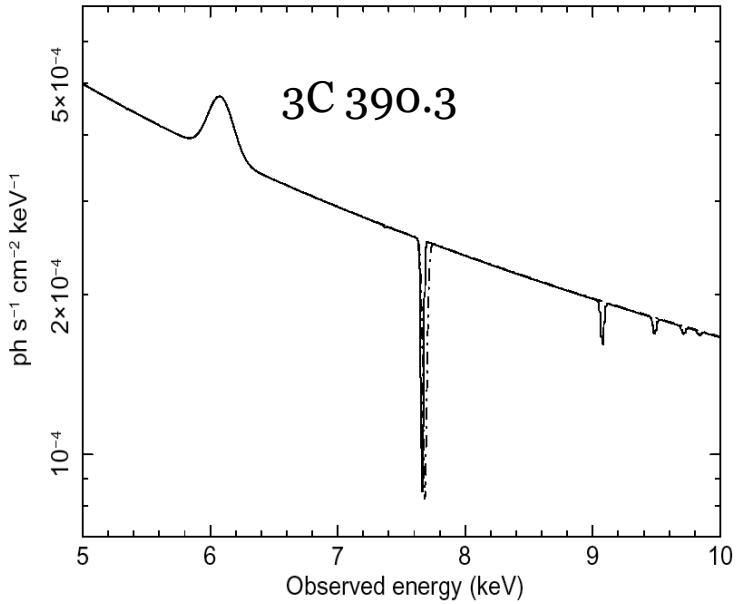
- detected absorption lines E>7keV in 3/5 sources
- unresolved Fe XXV K-shell and Fe XXVI Lyman series lines
- common blue-shifted velocity of lines ~0.04-0.15c (UFOs)
-

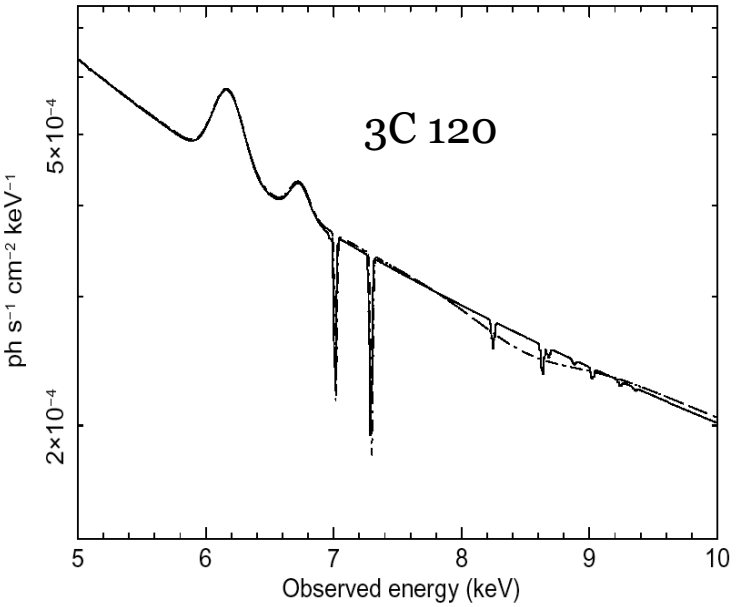
UFOs in BLRGs!

Source	$\log\xi$ (erg s^{-1} cm)	N_H (10^{22} cm^{-2})	v_{out} (c)
3C 111	5.0 ± 0.3	$> 20^a$	$+0.041 \pm 0.003$
3C 390.3	$5.6^{+0.2}_{-0.8}$	$> 3^a$	$+0.146 \pm 0.004$
3C 120a	...	...	...
3C 120b	3.8 ± 0.2	$1.1^{+0.5}_{-0.4}$	$+0.076 \pm 0.003$
3C 382	...	...	...
3C 445	...	...	...

(a) Lower limit at the 90% level.



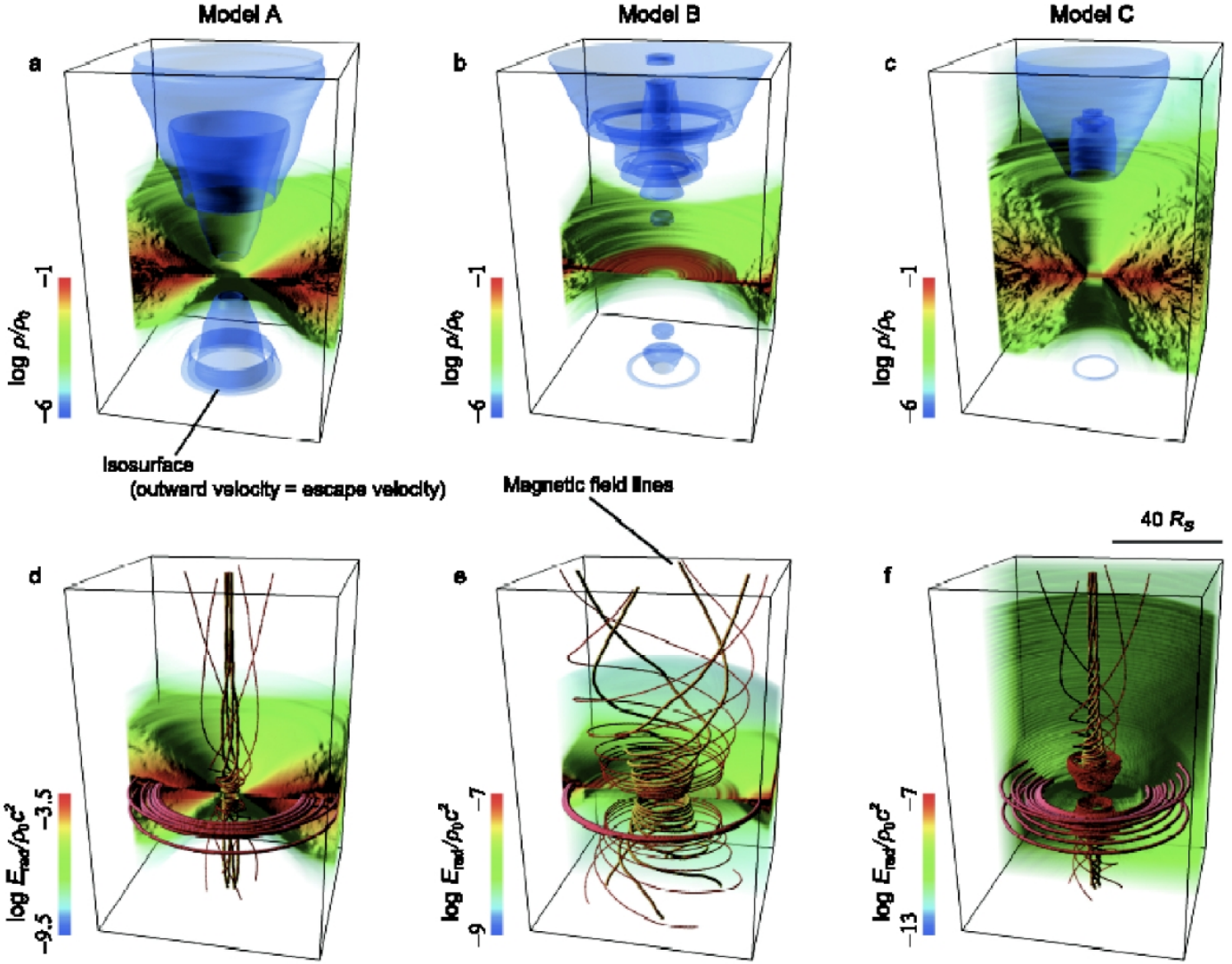




UFOs parameters

- Distances r<0.01-0.1pc (<10^2-10^5 r_s)
- v_{ufo}>v_{esc} not always, some blobs might fall back
- L_{bol}/L_{Edd}~0.01 (3C111) – 1 (3C120, 390.3)
- M_{out}/M_{acc}~0.1-1 *for covering factor ~0.6*
- E_k~10^{44}-10^{45} erg s^{-1} ~0.1 L_{bol} (~0.1-1 P_{jet})
- Similar to Seyferts (Tombesi et al. 2010b)

Unified model of inflow/outflow in AGN by Ohsuga et al. (2009)

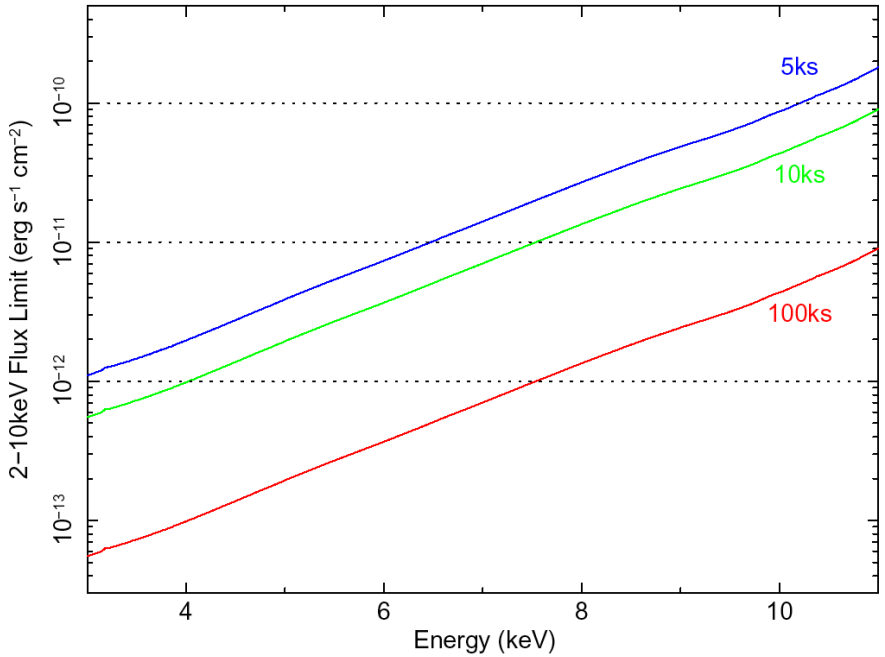


R-MHD simulations of inflow/outflow in AGNs. Three different modes controlled by density parameter. Massive and fast disk winds/outflows driven by radiation pressure. Collimated jets along polar axis driven by magnetic forces. **Disk winds and jets not mutually exclusive**; **UFOs in both RQ and RL AGNs**.

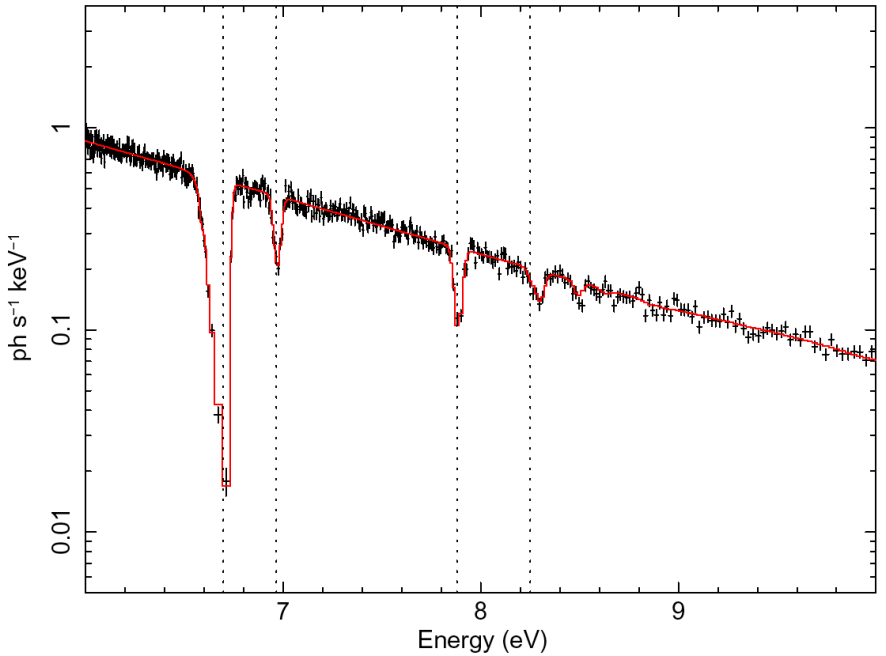
Open Questions

- What is the true covering factor of the gas?
  - mass and energy carried
  - role of wind for large-scale feedback in RL
- What are physical & dynamical characteristics of outflows in RL?
  - need to study line profile & variability
- Is there a link between jet and outflow in AGN?
  - correlated multiw. variability monitoring, e.g. GRS1915

The role of IXO - the XMS



Flux limits (EW=10eV) (Tombesi et al. 2009)



logξ=3 erg s^{-1} cm, N_H=10^{23}cm^{-2}, v_{tu}=1000km/s (Tombesi et al. 2009)

Flux limits

- 2-10keV flux limits for 5σ detection of narrow absorption lines in the 3-11keV
- Different EWs, exposure times and responses
- Lines of **EW=10eV (50eV) in ≈6-9keV for ≈10^{-12} (10^{-13})** erg s^{-1} cm^{-2} (expo 100ks)
- Spectral variability on time-scales **of 5 (10) ks** for ≈10^{-11} (10^{-12}) erg s^{-1} cm^{-2}

Realistic spectra simulations

- Simulations of highly ionized and massive absorbers
- FeXXV/XXVI K lines detectable with high significance
- Line details (profile, energy, broadening) measured with high accuracy (>30 times Astro-H)
- Extend search for UFOs to fainter sources
- Time variability, dynamics of absorbers

Conclusions

- X outflows with moderately relativistic velocities: new component of radio-loud AGN
- Link wind-jet-disk

- IXO (& multiw obs): major player for its physics